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Quarterly Progress Report #3

For the period December 1, 1962 to February 28, 1963

On

THE USE OF STRAIN SOFTENING TO IMPROVE THE PROPERTIES OF REFRACTORY METALS

Contract No. NOw62-0725-C

To

BUREAU OF NAVAL WEAPONS
Washington 25, D. C.

By

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ABSTRACT

The roller-flexing machine was completed and delivered during this report period. A few samples of Mo-1/2Ti were flexed at room temperature and at +300°F. On the basis of these preliminary data, a significant lowering of the transition temperature appears possible. In order to measure a complete longitudinal and transverse transition temperature on one or two flexed pieces, small bend samples are used for ductility evaluation. Surprisingly, it has been found that longitudinal flexing lowers the transverse transition at least as much as the longitudinal transition.

Because of a shortage of tungsten, all of the work during this period and probably the next one will be restricted to the molybdenum +0.5% titanium alloy. Only after evaluating the influence of a number of variables including number of cycles, working temperature and direction on the more plentiful molybdenum, will tungsten be used.

The amount of bending put into the sample during room temperature flexing is controllable and easily reproduced. At elevated temperatures, however, where the sample cannot be seen, the amount of bending has been a variable, and a modification in flexing technique will be required to assure a reproducible bending condition in each plate.

RESULTS AND DISCUSSION

Roller Flexer

The roller flexing machine was delivered during this report period. Although its operation was described in the First Quarterly Report (1), photographs of the completed machine are shown in Fig. 1, in order to aid in understanding its operation. Photograph (A) is an over-all front view, (B) an over-all rear view, (C) a close-up of the front end showing the back-up plates, opened clamps with a specimen in place, work rolls, back-up rolls and bearing housing, and (D) is an over-all view with the furnace in place.

Observation of the back-up and work rolls from the top indicate that even with the tightest clamping pressure, the rolls do not bow during rolling when one inch wide strips are flexed. The rack and gear arrangement apparently are effective in preventing bending, and it is expected that even six inch wide plate can be flexed with this apparatus.

One serious problem remains in machine operation, viz., developing a constant clamping pressure so that a reproducible amount of bending is developed in the plate. This appears to only require a modification in the loading procedure.

Method of Evaluation

In order to conserve tungsten, all of the preliminary work during this report period, and probably that conducted during most of the next period, will be done on the molybdenum 0.5% titanium alloy. The tensile properties vs. testing temperature curve of this alloy in the "as-received" condition has been obtained to serve as a base line for comparison with the flexed plate, Fig. 2. The measured values are consistent with those supplied by Universal-Cyclops. Tensile properties of the worked material will not be examined, however, until the characteristics of the operation are better understood, so that the initial evaluation is being made by the use of small bend samples. The flexed specimens are presently one inch wide and twelve inches long. End clamping required two to three inches of the sample ends so that the worked material has an area of one inch by six to seven inches. The bend specimens are one by one-half inch, so that approximately twelve tests can be carried out on each flexed member. A drawing of the bending jig is shown in Fig. 3. Note that it is limited to a maximum bend angle of approximately 135°.

The "as-received" bend transition of the molybdenum alloy is shown in Fig. 4. Because the NDT temperature is so well developed for these, this definition of transition temperature will be used for evaluating bend properties. The longitudinal and transverse NDT temperatures are -60 and -40°F respectively. The 105°bend transition reported by the Universal-Cyclops Corporation were -25 and +25°F for this material.

<u>Effect of Flexing</u>

Two samples were given 100 passes at room temperature. (That is, 50 passes of the flexing machine in each direction. Since there are two upper and three lower work rolls, each pass produces five bends in the strip.) The bend angle at fracture vs. testing temperature of these strips is shown in Fig. 5. Flexing reduced the longitudinal transition temperature by 20°F, and the transverse by 40°F. Properties obtained on the two flexed plates appear to be identical. The transverse samples exhibited a pronounced minimum in the upper shelf, however, and this dip was partially reflected in the longitudinal direction. As yet, no attempt has been made to explain this phenomenon.

Visual observation of the bend samples indicates that delamination is less severe in the flexed pieces than in the "as-received" material.

Two strips were also flexed at a higher temperature, Fig. 6. Because of interference from the furnace, it was difficult to know how much bending was being applied to the strip so that one was heavily crimped, and the other lightly. The strip given the smaller bend had the better properties, especially in the longitudinal direction. In this direction, the longitudinal transition was lowered $40^{\circ}F$, and the transverse $30^{\circ}F$.

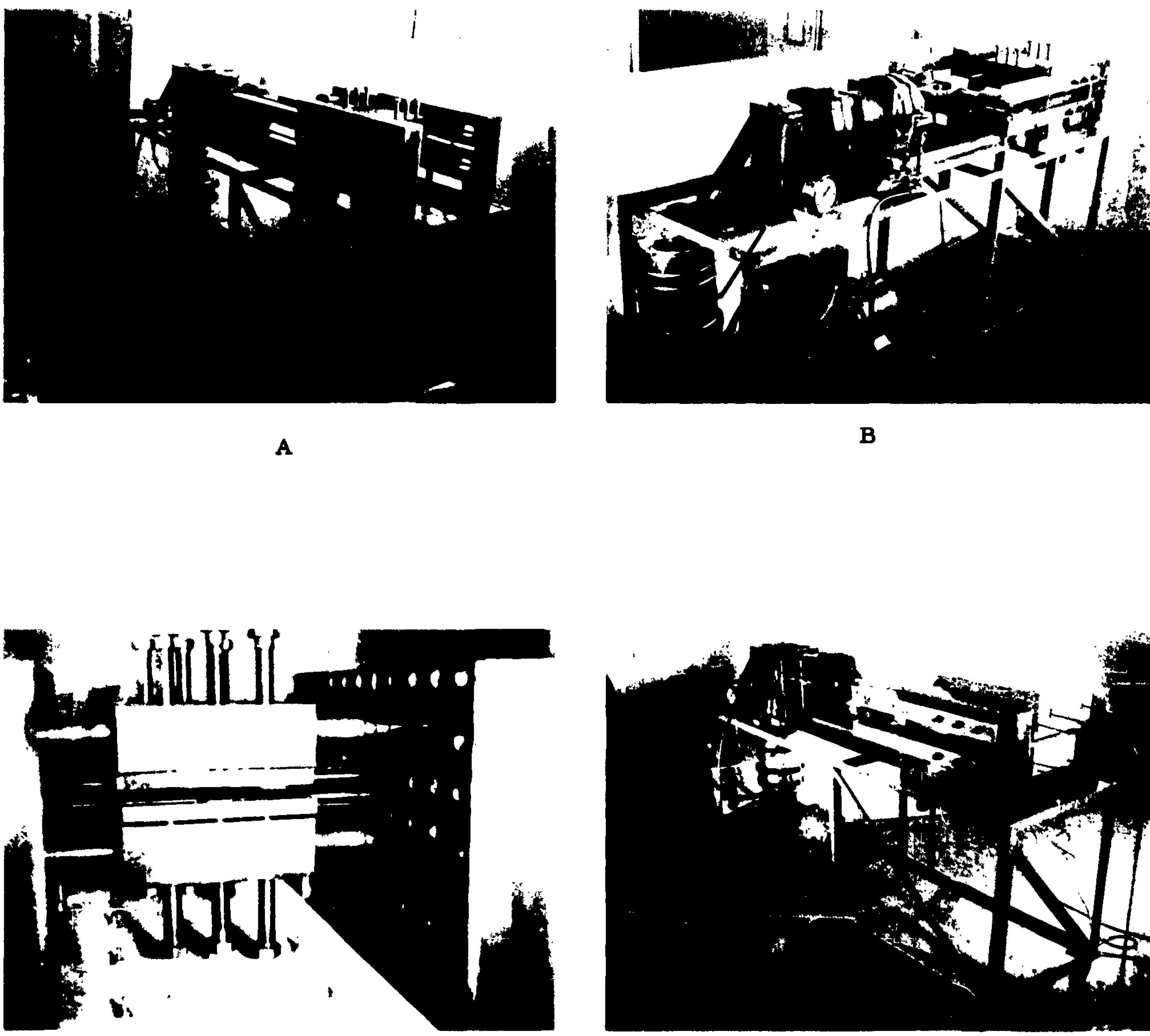
FUTURE WORK

It is the writers' opinion that the phenomena being uncovered in this project is a unique strain-aging behavior. For this reason, it is expected that the amount and type of working, as well as the forming temperature, can be optimized for each material. It might be mentioned that single direction warm-working studies being conducted by this laboratory indicate that, in general, the lowering of the transition temperature is essentially a function of the amount of working, and the height of the upper shelf a function of working temperature. The number of cycles, bend radius, working temperature, and flexing direction (longitudinal vs. transverse, or some combination of the two) are all variables to be studied. After optimizing the bend transition properties of the molybdenum alloy, its tensile properties will be measured.

Only after some significant experience is developed on molybdenum, will tungsten be flexed.

REFERENCES

1. S. Mostovoy and E. J. Ripling, Quarterly Progress Report #1 on "The Use of Strain Softening to Improve the Properties of Refractory Metals", Materials Research Laboratory, Inc., Contract #NOw-62-0725-C, June-August, 1962.



A B C D

Fig. 1 PHOTOGRAPHS OF ROLLER FLEXER. (A) Front View. (B) Rear View. (C) Close Up of Front End. (D) Overall View with Furnace in Place.

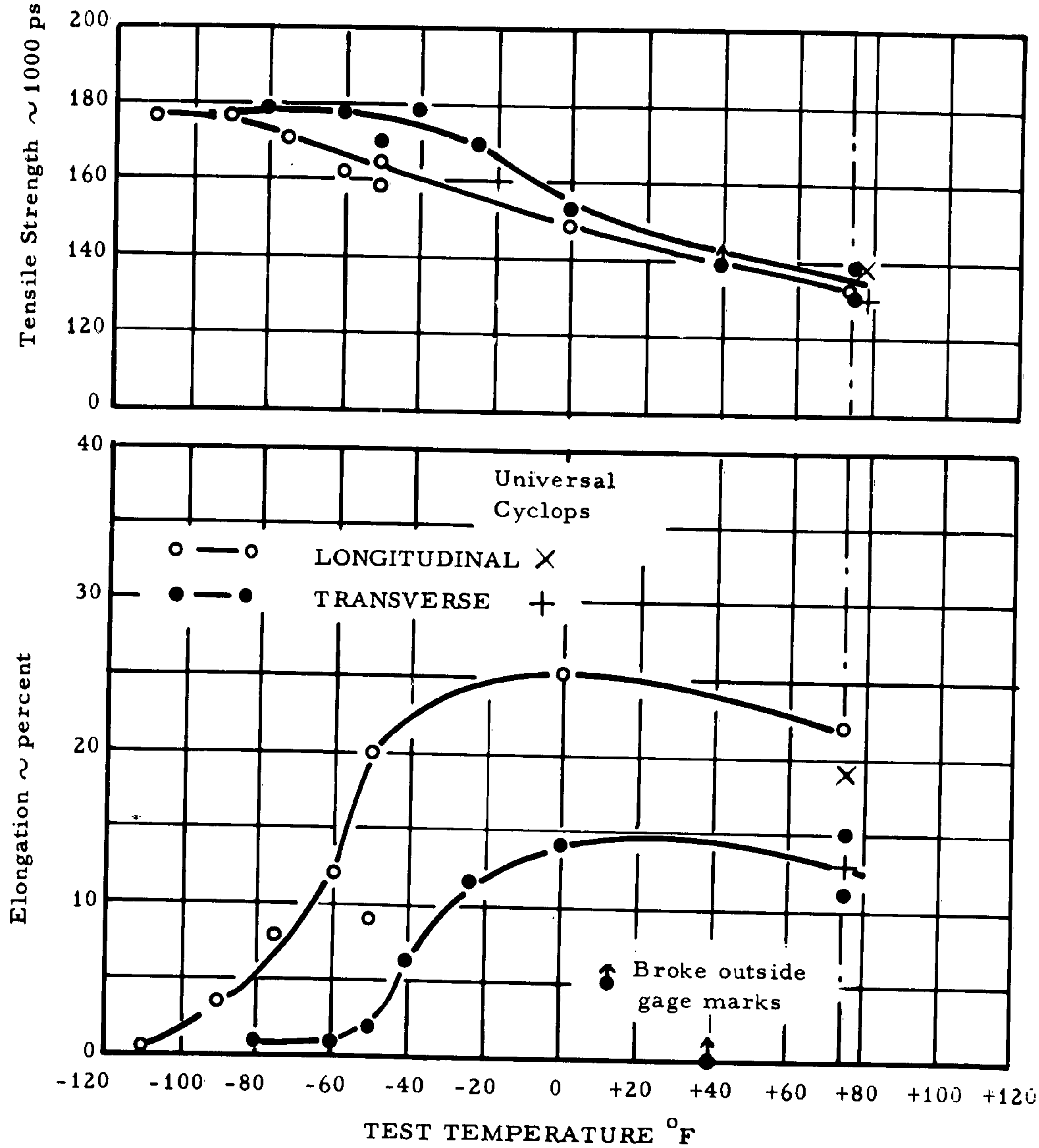


Fig. 2 TENSILE PROPERTIES OF "AS-RECEIVED" MOLYBDENUM--0.5% TITANIUM ALLOY.

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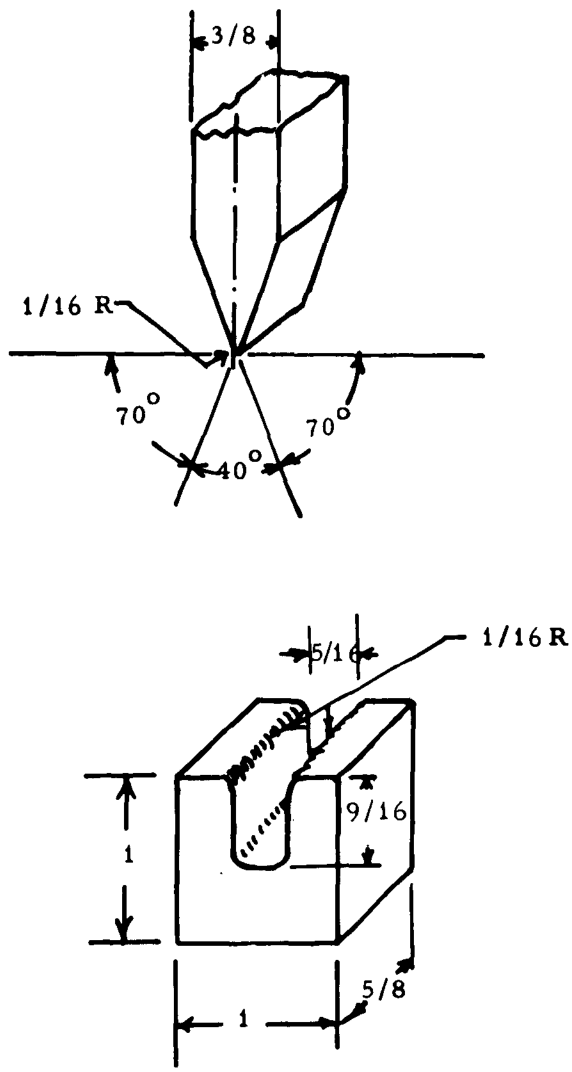

Fig. 3 SCHEMATIC DIAGRAM OF BENDING FIXTURE

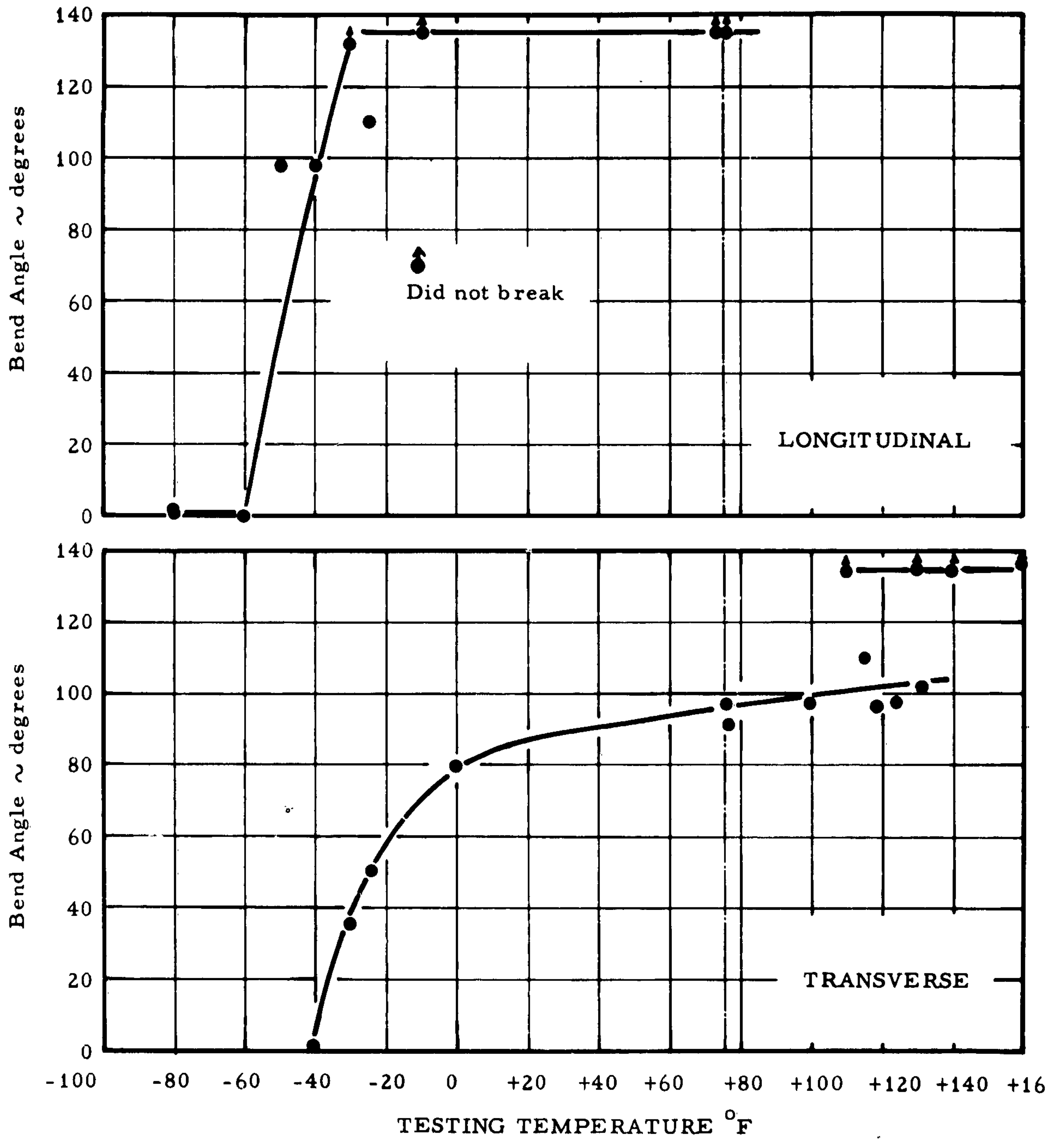

Fig. 4 BEND ANGLE VS. TESTING TEMPERATURE OF MOLYBDENUM--0.5 TITANIUM ALLOY - AS RECEIVED

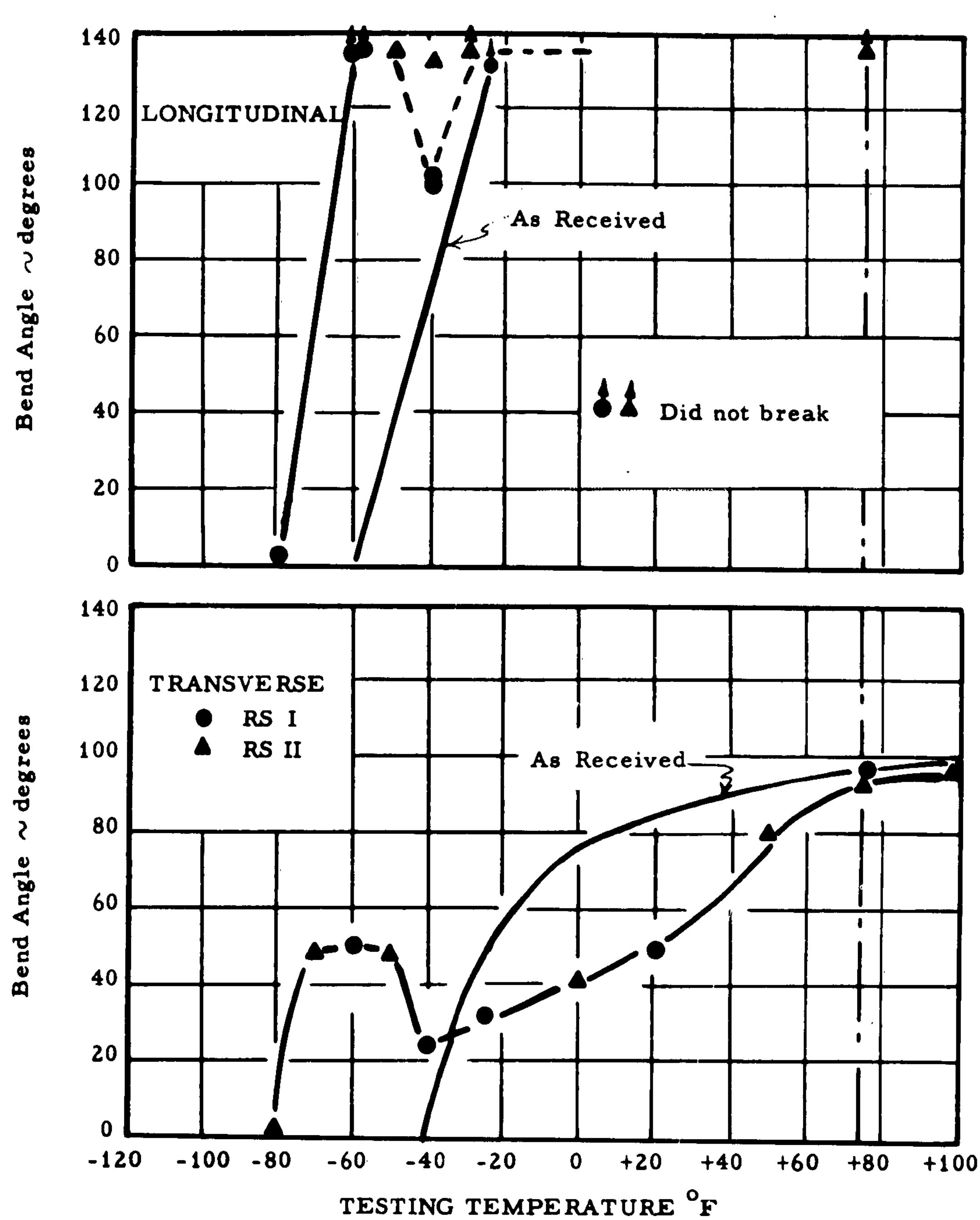

Fig. 5 BEND ANGLE VS. TESTING TEMPERATURE OF MOLYBDENUM--0.5 TITANIUM ALLOY - FLEXED 100 CYCLES AT ROOM TEMPERATURE

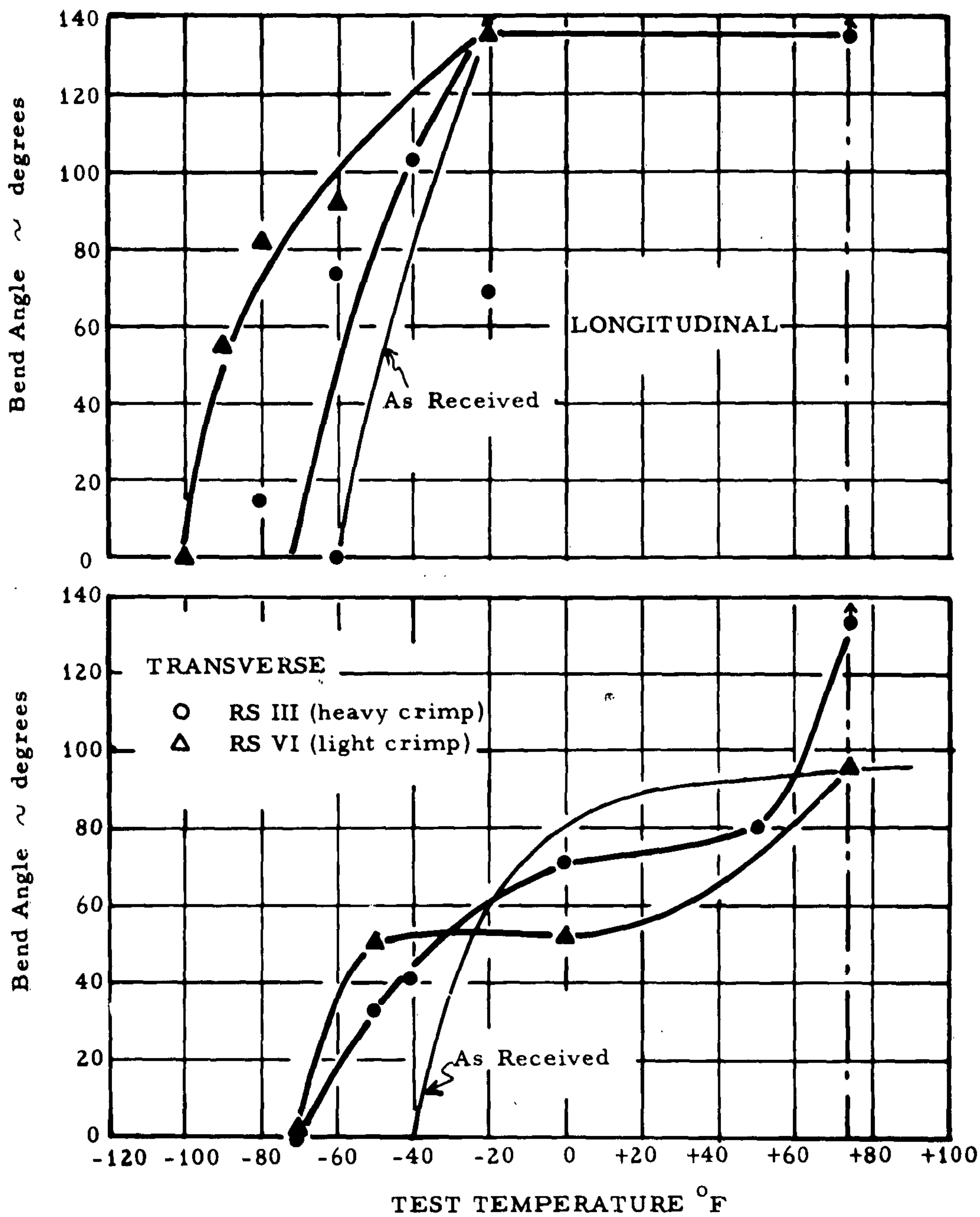

Fig. 6 BEND ANGLE VS. TESTING TEMPERATURE OF MOLYBDENUM--0.5 TITANIUM ALLOY - FLEXED 100 CYCLES AT +300°F.